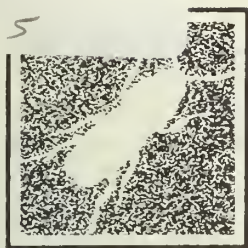


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1990 Insect Pest Management Guide

STORED GRAIN

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Grains produced in Illinois may be stored for periods of a few weeks to a few years before feeding or processing. The profitability of such storage depends not only upon marketing concerns, but also upon maintenance of grain quality. It is important to remember that the harvest and storage of grain does not signal an end to the possibility of losses caused by insects and pathogens.

Successful management of stored-grain insects is possible only when proper storage practices are carried out. Insecticides and fumigants should be viewed as supplements to, not replacements for, sound storage methods. Used properly, however, insecticides and fumigants can help to limit insect losses in stored grains without endangering the pesticide applicator or resulting in excessive pesticide residues that threaten the health of consumers (livestock or humans) of treated grain or grain products.

This publication provides recommendations for cultural and chemical control of stored-grain insects. It is revised annually; always use the current year's issue. Registration changes that occur between revisions will be announced to appropriate media sources and county Extension offices.

USING INSECTICIDES AND FUMIGANTS

The U.S. Environmental Protection Agency has designated certain pesticides for "restricted" use. The grain fumigants aluminum phosphide, chloropicrin, and methyl bromide are restricted-use pesticides. *Commercial* applicators must be certified in order to apply restricted-use pesticides. Elevator employees responsible for grain treatment at their place of employment must be certified under the category "Grain Facility Pest Control Applicator." Commercial fumigation professionals who treat stored grain or grain products at farms, elevators, warehouses, etc. must be certified by the Illinois Department of Public Health. A *private* applicator who wishes to purchase or apply restricted-use pesticides "for the purpose of protecting any agricultural commodity on property owned or rented by him or as exchange labor (no compensation) on the property of another" must obtain certification by passing an examination administered by the Illinois Department of Agriculture. **Regulations recently enacted by the Illinois Department of Agriculture mandate that private applicators must obtain**

special certification to purchase and apply grain fumigants. To obtain certification for fumigant application, individuals must first pass the private applicator exam and then pass a grain storage and fumigation exam.

Those who apply pesticides should be aware that the pesticide user is always responsible for the results of pesticide applications. To avoid accidents and maximize the effectiveness of any application, always read the pesticide label and follow all directions and safety precautions. Be sure that the pesticide is specifically labeled for the pest, site, and application method planned.

Remember: The label is the law.

Poison Resource Centers. The Poison Resource Centers listed below have been established to provide information about the treatment of poisoning cases. Anyone with a poisoning emergency can call the toll-free telephone number for help. Personnel at the Resource Center will provide first-aid information and refer callers to local treatment centers if necessary.

Poison Resource Centers supplement, but do not replace, local emergency medical services. Do not delay calling local emergency medical personnel to request immediate assistance or transportation. If possible, have the pesticide container and label present when you call or reach a treatment center or hospital.

Chicago and northeast Illinois
1753 West Congress Parkway
Chicago, Illinois 60612
Telephone: 800-942-5969

Northern and central Illinois
530 N.E. Glen Oak
Peoria, Illinois 61603
Telephone: 800-322-5330

Central and southern Illinois
800 East Carpenter
Springfield, Illinois 62702
Telephone: 800-252-2022

A national pesticide telecommunications network can be reached by dialing 1-800-858-7378.

NOTE: The information that follows is provided for educational purposes only. Reference to commercial products or trade names does not constitute an endorsement

ment by the University of Illinois and does not imply discrimination against similar products. Trade names are presented for reasons of clarity only. The reader is urged to exercise the usual caution in making purchases or evaluating product information.

INSECTS ATTACKING STORED GRAIN

Several types of insects inhabit stored grain. Exact identification of these insects often is difficult because most stored-grain pests are extremely small ($\frac{1}{16}$ to $\frac{1}{4}$ inch in length), and many separate species are very similar in appearance. Presenting identification information for the many species of stored-grain pests is not the purpose of this publication; materials containing such information are included in the reference listing at the end of this circular. It is important, however, to recognize the different groups of insects that live in stored grains because management considerations may differ according to the insects' characteristics.

Weevils and Other Insects that Feed Inside Kernels

The most damaging insect pests of stored grain are those that develop within grain kernels. These insects are referred to as internal pests or primary pests. Adults deposit eggs on or in whole kernels, and larvae develop hidden within kernels. Damage caused by internal pests makes grain more suitable for infestation by insects that feed externally on grain or grain debris.

The common primary pests of grains in Illinois are the weevils — rice weevil, maize weevil, and granary weevil. The grain weevils are small (between $\frac{1}{16}$ and $\frac{1}{8}$ inch in length), but recognizable as a group because the head bears a prolonged snout. Another primary pest found in wheat, but only rarely in corn, is the lesser grain borer. Recognition of this pest is possible because the adult lesser grain borer's head projects downward, not forward, from the anterior portion of the body. These insects may be found in any portion of the grain mass within a bin; they are not restricted to portions near the surface.

The larval stages of the Angoumois grain moth also feed within grain kernels. This insect can infest grain in the field; storage infestations are limited to near the surface of the grain mass.

Beetles that Develop and Feed Outside Grain Kernels

Most insects commonly collected in stored grain in Illinois are beetles that range in size from $\frac{1}{16}$ inch to over $\frac{1}{2}$ inch in length. Adults of most species are reddish brown to black in color, and their forewings are hardened to form a "shell" over the body. Larvae of common species are cylindrical and cream-colored; some bear fine hairs. Species frequently collected in Illinois grain bins include the sawtoothed grain beetle, flat grain beetle, rusty grain beetle, foreign grain beetle, hairy fungus beetle, larger black flour beetle, red flour beetle, and confused flour beetle.

Like the weevils, beetles that feed and develop

outside grain kernels are not limited in distribution to the grain surface, but instead inhabit any portion of a grain mass. They feed on several different grains, but their buildup in any grain usually results from an abundance of broken kernels (fine material) or fungal growth on moist grain. Their dependence on fines or fungal growth accounts for the description of these insects as "secondary" pests, "bran bugs," or "fungus feeders." Concentrations of stored-product beetles cause an increase in grain moisture and temperature, and such changes favor continued population growth.

Surface-Feeding Caterpillars

Caterpillars that feed in stored grain inhabit primarily the outer portions of the grain mass (usually the grain surface, but also the bottom of the grain mass just above perforated drying floors or aeration ducts). These caterpillars reach approximately $\frac{3}{4}$ inch in length and are cream-colored. They produce fine, silken webbing as they move about near the grain surface. Mature larvae pupate within a silky cocoon. Adult moths fly and mate in the bin headspace where they may be seen resting on the bin walls and roof.

The Indianmeal moth is the most common surface-feeding caterpillar in stored grain in Illinois. The adult Indianmeal moth has a wingspan of about $\frac{3}{4}$ inch; the outer half of each front wing is reddish brown or copper-colored. Malathion resistance appears to be common in Illinois populations of Indianmeal moth. Other surface-feeding caterpillars include the Angoumois grain moth (which feeds within kernels), the Mediterranean flour moth, and the meal moth.

Other Stored-Grain Insects

Additional pests that sometimes infest stored grains include psocids (booklice) and grain mites. These soft-bodied pests feed on grain-rotting fungi. An abundance of psocids or grain mites often indicates a more important problem of mold-related deterioration of the grain.

Remember that not all insects in grain are pests. Parasitic wasps, larvae of a predaceous fly species, and predaceous Hemipterans (true bugs) attack certain grain pests. In addition, many field insects are inadvertently transported to grain bins where they cause no damage.

PREVENTION OF INSECT INFESTATIONS

Sources of Infestations

Some stored-grain insects can infest maturing grain crops in the field. Although some field infestations probably occur in Illinois, the extent of field-originated storage problems appears to be minor.

The most common sources of stored-grain insects are old grain, grain spills, feeds, seed, and grain debris. Insects often move to new grain from carry-over grain, from small amounts of grain not cleaned from "empty" bins, from feed supply buildings, and from grain debris beneath perforated floors of bins. Most pest species can fly at least short distances to reach new grain.

Sanitation

To minimize the migration of stored-product insects from current food sources to new grain, thorough cleanup practices are necessary. At least 2 weeks before storing new grain, clean all grain and grain debris from within and around grain bins. Be thorough; sweep or vacuum bin floors. Also remove and feed or destroy any grain and grain debris in combines, wagons, augers, etc. If grain debris is not removed from the combine, collect and feed or destroy the first few bushels of grain that pass through the combine.

Bin Sprays and Empty-Bin Fumigation

Insects may remain in certain bin locations even after a thorough cleanup is completed. Hard-to-clean sites that harbor insect pests include cracks and crevices in bin walls and the plenum beneath nonremovable perforated floors. Applying an insecticide or a fumigant in an empty bin can supplement (but not replace) physical cleanup efforts.

Apply an insecticide to the walls, ceiling, roof, and floor of all bins that will be used to store grain for more than a few weeks. Use:

- 4 fl oz malathion 57% EC in 2 gal water;
or
- 1 qt methoxychlor 25% EC in 2 gal water;
or
- 12 oz methoxychlor 50% WP in 2 gal water;
or
- 4 fl oz Reldan 4E (chlorpyrifos-methyl) in 3 gal water.

Spray all bin surfaces to the point of runoff, and be sure to thoroughly treat all cracks and crevices and around doors. Directing extra spray to and through perforated flooring will provide some control of insects living in grain debris in the subfloor plenum, but satisfactory control of insects in this space requires fumigation (or removal of the false floor to allow complete cleanup of debris in the plenum).

Fumigating empty bins to control insects in the subfloor plenum may be necessary if summer-harvested grain (wheat, etc.) is to be stored in the bin 1 month or longer or if fall-harvested crops (corn, soybeans, or grain sorghum) will be stored beyond May or June of the year following harvest. Empty bin fumigation is usually not necessary where grain will be treated with a protectant insecticide at the auger as it is binned. The fumigant chloropicrin (trade names are Chlor-o-pic, Larvacide 100, and Quasar) is labeled and effective for empty bin fumigation.

Chloropicrin is a restricted-use pesticide that is extremely toxic. The U.S. Environmental Protection Agency recently revised fumigant regulations to require the use of a canister respirator (gas mask) or self-contained breathing apparatus (SCBA) if applicators are exposed to chloropicrin. Fumigators also must measure fumigant gas concentrations to determine that the fumigant has dissipated sufficiently before unprotected persons can enter the fumigated space. Follow specific

label directions concerning respiratory protection equipment and gas detection devices. Failure to follow all label instructions is unsafe and illegal. If you are uncertain about the safe use of a fumigant, contact the manufacturer for detailed recommendations.

Use chloropicrin only on relatively calm days when the outside air temperature is 65°F or higher. Before applying chloropicrin, use tape and polyethylene sheeting to seal the side door and all bin openings below the level of the side door. Be sure to seal fan openings and the unloading auger shaft. Post warning placards according to label directions. Always have a partner present when applying this or any other fumigant.

To fumigate the subfloor plenum of empty bins, pour in chloropicrin from a ventilation door on the bin roof. Wear a canister respirator equipped with a fresh canister when applying chloropicrin and climbing down from the bin roof. Use 1 quart per 250 square feet of floor area. Chloropicrin forms a pungent tear gas that settles in the lower portion of the bin. This gas will kill all stages of stored-grain insects beneath the subfloor, but chloropicrin will not spread to the upper portions of the bin to kill insects suspended in grain debris remaining on bin walls. Wait at least 24 hours before airing out the bin.

Filling the Bin

Effective insect management in stored grain starts with good grain storage practices. Use a grain cleaner to minimize the amount of fine material that is binned along with the grain. Many species of stored grain insects cannot survive in the absence of broken kernels and grain debris. Use of a grain spreader evenly distributes remaining fine material and helps to level the grain surface. Once the bin is full, if fine material is concentrated in a central core beneath the auger spout, removal of one or a few loads from the bin will extract this core of fines. Do not add new grain on top of old because insects will rapidly move from the infested grain to the new crop. Do not overfill bins; the levelled grain surface should be at least a few inches below the lip of the bin. Levelling the grain surface is important for uniform airflow and for effective insecticide or fumigant application.

Store only dry grain. Maintaining moisture levels that prevent the growth of storage fungi is sufficient where fall-harvested grain is to be stored only through the winter, but grains that will be stored 1 month or longer during warm, summer weather should be dried to 12-13 percent moisture. This moisture content is unfavorable for most grain insects; it also allows prolonged persistence of protectant insecticide residues.

Aerate to cool stored grain as soon as possible. Temperatures below 50°F prevent insect feeding and reproduction. Cooling grain to just above freezing will kill some stages of many grain insects. Aeration also results in uniform temperatures that prevent moisture migration problems within a bin. Most grain storage

references recommend aerating to maintain grain temperatures within 15°F of average outdoor temperatures. These references also usually discourage the use of aeration to cool grain below freezing.

Grain Protectants

Application of insecticides directly to grain to prevent insect infestation is warranted if grain is to be stored more than 3 to 6 weeks at grain temperatures above 60° to 70°F. Summer-harvested grains that are to be stored 1 month or more and fall-harvested grains that are to remain in storage beyond May or June of the year following harvest should be treated with a protectant insecticide. Incorporating a surface treatment is adequate for short-term protection. However, uniform application to all grain at the auger is necessary for long-term protection. Where grain protectant insecticides are applied at labeled rates, grain can be processed or fed to livestock with no waiting period.

In order to protect against stored-grain beetles and weevils throughout the entire mass of grain within a bin, a protectant insecticide must be applied uniformly to all grain as it is augered into the bin. Drip-on or spray-on applicators can be mounted on the auger to apply liquid formulations. Dusts can be applied using an auger-mounted applicator, or they can be spread over a truck or wagon just before unloading. Protectant insecticides should not be applied to grain before high-temperature drying. Once grain is in the bin, surface or "cap-off" applications of protectant insecticides are effective only against the insects that are feeding at the grain surface. A surface dressing or "cap-off" treatment may be used to give some control of insects entering the top of the grain mass. Surface treatments often provide adequate protection where previously unin-fested grain is to be stored at warm temperatures for a month or two. For longer storage at warm temperatures, adequate control requires treating the entire grain mass at the auger as the grain is binned. Table 1 summarizes uses for registered grain protectants.

Crop-specific recommendations for the use of protectant insecticides are:

Corn. It is not necessary to apply any insecticide to new-crop corn that will be removed from storage by May or June of the following spring. Similarly, if corn will be used on site as livestock feed (and not subject to grading associated with sale) within one year of harvest, use of a protectant insecticide usually is not necessary. For storage periods of 1 year or longer, apply Actellic or malathion at the loading auger using rates listed in Table 1. Reldan is not registered for use on corn. Do not apply insecticides before high-temperature drying because extreme heat will result in rapid volatilization and reduction in residues. For malathion residues to persist on corn at effective levels through the summer following harvest, corn must be dried to approximately 12 percent moisture. Data indicate Actellic residues will

persist for a similar period on grain stored at 14 percent moisture.

Malathion will not control Indianmeal moth. Where malathion is applied at the auger as corn is binned, incorporate *B.t.* in the top 4 to 6 inches of the grain once the bin is filled and levelled or by May of the following spring to prevent infestation by Indianmeal moth larvae. Diatomaceous earth may also be used as a topdress treatment to control Indianmeal moth larvae.

Long-term storage programs usually allow "rotating" corn in storage — shipping out old corn and replacing it with the new crop each year. Annual rotation of stored corn helps to avoid buildup of insect infestations. Where annual rotation is practiced, topdress treatments of malathion plus *B.t.* or Actellic alone applied in April or May usually provide adequate control without treating the entire grain mass.

Soybeans. Only Indianmeal moth will infest soybeans stored at moisture levels that prevent mold growth. To protect against Indianmeal moth infestation, rake in surface applications of *B.t.* or diatomaceous earth once the bin is filled and levelled or by May of the following year. No other protectant insecticides are registered for application to stored soybeans.

Wheat. Wheat is especially vulnerable to insect infestation because it is harvested in midsummer when stored-product insects are active within and outside storage facilities. Warm temperatures in summer-harvested wheat also contribute to the rapid development and reproduction of insects within bins.

Apply malathion or Reldan at the loading auger to all wheat that is to be stored for 1 month or more. Where malathion is used, also incorporate *B.t.* or diatomaceous earth in the top 4 to 6 inches of grain to prevent Indianmeal moth infestations. Reldan controls Indianmeal moth and the weevils and "secondary" beetles that infest grain.

Sorghum. For storage periods of 1 year or longer, apply Actellic, malathion, or Reldan at the loading auger, but not before high-temperature drying. For malathion residues to persist at effective levels through the summer following harvest, grain must be dried to 12 percent moisture content; Actellic and Reldan should persist for 12 months or more on 14 percent moisture sorghum. Where malathion is applied, also rake in surface applications of *B.t.* or diatomaceous earth once the bin is filled and levelled or by May to control Indianmeal moth. Where sorghum has not been treated at the auger as it was binned, topdress applications of Actellic, Reldan, or malathion plus *B.t.* usually will provide adequate protection for one summer's storage if application is made by April or May.

Insecticide Resistance in Stored-Grain Insects

Insecticide resistance is an important worldwide problem that is especially common (on an international

Table 1. Insecticides registered for use to protect stored grain. Grains treated with protectant insecticides at labeled rates as specified below can be fed to livestock or processed for feed or food uses with no waiting period.

Insecticide	Registered for use on:	Rate/1,000 bu	Restrictions; Comments
malathion 57% EC, 6% D, 4% D, and 2% D	corn, wheat, oats, barley, rye, sorghum, sunflower	1 pt 57% EC in 2-5 gal water; 10 lb 6% dust; 15 lb 4% dust; or 30 lb 2% dust. Use the same amount/1,000 sq ft of grain surface as a "cap-off" treatment <i>if the entire grain mass is not treated.</i>	Do not apply to soybeans. Malathion will not control Indianmeal moth. Dry grain to 12% moisture in order for malathion to persist for 1 year or more. Do not apply prior to high-temperature drying. Cap-off treatments do not provide control of insects already active beneath the treated layer.
chlorpyrifos-methyl (Reldan 4E, 3% D)	wheat, oats, barley, sorghum	barley — 9.2 fl oz; oats — 6.2 fl oz; sorghum — 10.7 fl oz; wheat — 11.5 fl oz. Apply in 1 to 5 gal water. Use 10 lb 3% dust/1,000 bu. Use 1.6 to 3.0 fl oz 4E or 7 lb 3% dust/1,000 sq ft of grain surface as a "cap-off" treatment <i>if the entire grain mass is not treated.</i>	Do not apply to corn or soybeans. Controls weevils, secondary beetles, and Indianmeal moth. Dry grain to 14% moisture in order for chlorpyrifos-methyl to persist for 1 year or more. Do not apply prior to high-temperature drying. Cap-off treatments do not provide control of insects already active beneath the treated layer.
<i>Bacillus thuringiensis</i> (Bactospeine, Dipel, SOK-Bt, and Thuricide)	corn, soybeans, wheat, oats, barley, rye, sorghum, sunflower	Rate depends on product concentration. Follow label directions.	Use to control Indianmeal moth larvae. Controls only larval stages; must be ingested. Apply to the top 4 to 6 inches of grain as it is augered into the bin or incorporate by raking once the bin is filled.
pirimiphos-methyl (Actellic 5E)	corn (including popcorn), sorghum	8.6 to 11.5 fl oz in 5 gal water. Use 3 fl oz in 2 gal water/1,000 sq ft surface area as a "cap-off" treatment <i>if the entire grain mass is not treated.</i>	Do not apply to soybeans, wheat, barley, or oats. Controls weevils, secondary beetles, and Indianmeal moth. Dry grain to 14% moisture for pirimiphos-methyl to persist for 1 year or more. Do not apply before high-temperature drying. Cap-off treatments do not provide control of insects already active beneath the treated layer.
diatomaceous earth	corn, wheat, oats, barley, rye, sorghum, soybeans, sunflower	Follow label directions.	See text, page 6.
methoprene (Diacron, 65.7% a.i.)	corn, wheat, sorghum, barley, oats	wheat — 7.7 fl oz; corn and sorghum — 7.1 fl oz; barley — 6.1 fl oz; oats — 4.1 fl oz. Apply in 5 gal water.	Do not apply to soybeans. Prevents normal development of immature stages of insects but will not kill adult insects. Apply as a preventative. Do not apply more than once per crop.
pyrethrins plus piperonyl butoxide	corn, wheat, oats, barley, rye, sorghum, sunflower	Rate depends on product concentration. Follow label directions.	Do not apply to soybeans. Short-term residual activity. Useful mainly as a surface spray to control larval and adult Indianmeal moths as well as other pests at the grain surface.

scale) in stored-product insects. In Illinois, resistance to malathion is widespread among Indianmeal moth populations throughout the state. Some Illinois populations of the red flour beetle are resistant to malathion, but the range and intensity of this resistance problem in Illinois are not well known. Populations of the hairy fungus beetle collected in northern Illinois are resistant to both Actellic and malathion; the geographical range of resistant populations of this species is not known.

Special Review of Dichlorvos

Resin strips containing the insecticide dichlorvos (DDVP, Vapona) have been used for several years in grain storages to control the adult Indianmeal moth in

the storage headspace. Originally known as "No-Pest Strips," these insecticide devices have been sold under several trade names.

As a result of studies commissioned by the National Toxicology Program, the U.S. Environmental Protection Agency (U.S. EPA) has recently classified dichlorvos as a probable human carcinogen. The U.S. EPA has initiated a "Special Review" of dichlorvos to evaluate the benefits and risks associated with its use in a variety of pest control situations. The results of that review will determine the future of dichlorvos registrations and uses.

Until further information clarifies the risks associated with the use of dichlorvos, and until the Special Review

results in continuation or cancellation of current registrations, grain handlers are advised to discontinue the use of dichlorvos for stored-product insect control.

Methoprene

The U.S. EPA recently approved registration of the insect growth regulator methoprene (trade name Diacon) for use on stored grains (but not soybeans). Methoprene is a compound similar to the naturally occurring juvenile hormones of insects. Its acute toxicity to mammals is very low. The active ingredient methoprene interferes with the growth and maturation of immature stages of insects. It will not control adult insects already present in grain, but it will prevent immature stages from developing to adults and reproducing. Insects listed on the Diacon label include the Indianmeal moth, cigarette beetle, lesser grain borer, sawtoothed grain beetle, merchant grain beetle, red flour beetle, and confused flour beetle.

Current labeling for Diacon allows its use as an empty-bin spray and as a direct spray on grain as it is augered or conveyed into storage; no instructions for surface topdress application are included on the Diacon label. Because methoprene does not kill adult insects, this compound should not be used to provide rapid control of existing infestations.

Diatomaceous Earth

Diatomaceous earth is an abrasive and slightly sorptive dust that damages an insect's body covering and causes death by dehydration. Applied at high rates (120 to 300 lb/1,000 bushels of grain), diatomaceous earth is a fairly effective protectant against several stored-grain insects. Labels for the diatomaceous earth product Insecto recommend application of 28 to 56 lb/1,000 bushels of corn. Field data supporting the effectiveness of rates in this range are lacking. For long-term protection, diatomaceous earth must be applied at the auger as grain is binned so that it is distributed evenly throughout the grain mass within a storage. Incorporating surface treatments should provide some control of insects active in the treated layer. Labels for Insecto recommend monthly applications of 1 lb/1,000 sq ft of surface area; field data supporting the efficacy of this low rate are lacking. Problems associated with the use of diatomaceous earth as a grain protectant include increased wear to grain-moving equipment, the generation of great amounts of airborne dust during grain handling, and possible reductions in grain grade and test weight. Some buyers refuse to accept grain treated with diatomaceous earth. One successful and practical use of diatomaceous earth has been its addition to small seed packets to prevent infestation by stored-product pests.

SAMPLING STORED GRAIN

Stored grain should be monitored regularly to determine grain moisture content and temperature and to

detect any insect infestations. Sample stored grain for insects at least monthly from November through April and at least twice monthly from May through October. Pay particular attention to the grain surface and the central core of the grain mass, but also sample additional locations and depths. Be sure to examine grain from any locations where temperature or moisture readings are substantially higher than average. Deep bin probes and sectioned grain triers are most commonly used for withdrawing samples from beneath the grain surface. Probe traps and sticky pheromone traps also are available for monitoring insects within the grain mass and flying moths, respectively. Sampling equipment is available from most bin sales and service companies.

CONTROLLING ESTABLISHED INFESTATIONS

When insects are found in stored grains, a logical question is "Are there enough insects present to warrant control?" Unfortunately, this question is hard to answer. The importance of an insect infestation is determined not only by insect numbers, but also by type of grain, insect species, time of year, grain temperature and moisture, the planned duration of storage, market potential, and local elevator quality and dockage guidelines. Revised (1988) Federal Grain Inspection Service (FGIS) standards for grain insect infestation are presented in Table 2, but local elevators usually enforce more stringent standards. Insect-damaged kernels also may result in price discounts. Consider too that insect populations and their damage can increase rapidly.

When insects are detected in stored grain, consider several possible management practices. Sometimes the most profitable action can be to clean and sell the grain immediately without any chemical treatment. Immediate sale can be especially appropriate where early stages of insect infestations are detected before insect numbers reach elevator detection or discount levels. During cool weather, aerating to cool the grain to below 50°F can prevent insect activity and allow an extended period of safe storage.

Sometimes insect problems may be limited primarily to the surface or central core of stored grain. If Indianmeal moth is the only problem, light infestations can

Table 2. The number of live insects (per kilogram of grain) required for FGIS designation as "infested"

Crop	Insect density for designation as "infested"
Wheat, Rye, Triticale	<ul style="list-style-type: none"> • More than 1 live weevil, or • One live weevil plus any other live stored grain insect pest, or • No live weevils, but 2 or more other live pest insects.
Corn, Barley, Oats, Sorghum, and Soybeans	<ul style="list-style-type: none"> • More than 1 live weevil, or • One live weevil plus 5 or more other live pest insects, or • No live weevils, but 10 or more other live pest insects.

be controlled by using *B.t.*, Actellic, Reldan, or diatomaceous earth as outlined in Table 1. Unincorporated applications of these insecticides will not control Indianmeal moth larvae already present a few inches below the grain surface. Where abundant webbing indicates a severe infestation, webbing should be raked from the surface before treating; fumigation may be necessary in these situations. Where secondary beetles are confined primarily to a central core of fine material, removing 1 or 2 loads of grain to extract that core can allow safe storage of the remaining grain.

Where infested grain can be moved to a clean bin, transfer and treatment with a protectant insecticide (see Table 1) is recommended. If possible, use a grain cleaner during the transfer process. Protectant insecticides will not immediately kill immature insects within grain kernels, but residues will eventually provide control and protect against reinfestation for a period dependent upon grain moisture and temperature.

Infested grain that cannot be treated successfully in any other way should be fumigated. The U.S. Environmental Protection Agency has prohibited the use of fumigants containing ethylene dibromide (EDB), ethylene dichloride (EDC), carbon bisulfide, or carbon tetrachloride.

Suspension of most liquid fumigant registrations, coupled with increased safety concerns and protective equipment requirements for remaining fumigants, signals the fact that fumigation of farm-stored grain is a potentially dangerous and difficult operation. Hiring a professional fumigator is recommended, especially for fumigation of bins with capacities greater than 5 to 10 thousand bushels.

Fumigation Steps

Persons not trained and certified specifically in the use of grain fumigants should not attempt to fumigate stored grain. The steps outlined below provide general guidelines, but not complete directions.

1. Level the surface of the grain, break up any caked or crusted areas, and remove any surface webbing.

2. Use tape and plastic sheeting to thoroughly seal all cracks and holes in the bin; seal the side door, unloading auger shaft, and fan openings. If the grain surface will not be tarped, also seal the eaves and roof hatches. Leave only the necessary access openings to seal after fumigant application. If the grain surface is to be tarped, tuck the plastic tarp along one edge of the structure so that it can be rolled out easily once the fumigant has been applied.

3. Spray the outside surface of the bin with malathion (4 fl oz 57% EC/gal water), chlorpyrifos-methyl (4 fl oz Reldan 4E/3 gal water), or methoxychlor (1 qt 25% EC or 12 oz 50% WP/2 gal water).

4. Learn and follow all safety precautions. Always work in pairs; an observer should be present *outside* of the bin. The U.S. Environmental Protection Agency recently revised fumigant regulations. New labeling re-

quires the use or availability of a self-contained breathing apparatus for respiratory protection during one or more stages of the fumigation process. Fumigators also must measure fumigant gas concentrations to determine that the fumigant has dissipated sufficiently before unprotected persons can enter the fumigated space. Follow specific label directions concerning respiratory protection equipment and gas detection devices. Failure to follow all label instructions is unsafe and illegal. If you are uncertain about the safe use of a fumigant, contact the manufacturer for detailed recommendations.

5. Choose a calm, warm day when the grain temperature is above 60° F. Apply a liquid or solid fumigant. Only those fumigants containing aluminum phosphide are registered for use on soybeans.

Chloropicrin (Chlor-o-pic, Larvacide 100, and Quasar) is a restricted-use liquid fumigant labeled for probe and surface application to stored grain. Protective clothing and respiratory equipment must be worn during application. Use 2.5 lb/1,000 bushels of wheat, barley, or rice; 3.0 lb/1,000 bushels of corn; 3.5 lb/1,000 bushels of oats; or 4.5 lb/1,000 bushels of grain sorghum. To provide successful control, chloropicrin must be applied by probes into the grain mass and uniformly onto burlap bags spread over the grain surface. Wait at least 72 hours before airing out; fumigated grain must be thoroughly aerated before processing or feeding.

Chloropicrin's use as a grain fumigant is scheduled to be discontinued. Its use as an empty-bin fumigant will not be altered by this action.

Dry fumigants containing aluminum phosphide include Detia, Fumitoxin, Gastoxin, Phostek, and Phostoxin. Aluminum phosphide is a restricted-use fumigant. A special application probe is required to place aluminum phosphide tablets or pellets in the grain mass. Use 180 tablets or 300 pellets per 1,000 bushels of bin capacity. Do not allow water to come in contact with tablets or pellets; wear neoprene or cotton gloves to prevent perspiration from reaching the dry material. During application, fumigant concentrations must be monitored using detector tubes to determine the need for respiratory protection.

6. Following application, finish tarping the grain surface or seal the access door that served as an exit from the bin. Place warning signs as directed by the fumigant label.

7. Wait at least 72 hours before airing out bins following aluminum phosphide or chloropicrin application; follow label directions. After aeration, fumigant concentrations must be measured before warning placards can be removed and before the grain can be fed or processed.

An additional fumigant that is effective and registered for application to stored grain is methyl bromide. Safety concerns and equipment requirements limit the use of methyl bromide to application by professional fumigators.

The atmospheric gases carbon dioxide and nitrogen

(alone or in combination) can be used successfully as grain fumigants. These gases are supplied for fumigation by stationary or portable generators or delivered in pressurized tanker trucks. The fumigant gas must be introduced into a storage in a manner that displaces the original air volume; then an adequate concentration (usually around 40 to 60 percent by volume) must be maintained for a period of 4 to 10 days (longer in cool grain). For these reasons, thorough sealing is especially important. Fumigation with atmospheric gases leaves no toxic residues once the treated commodity is aerated, but it is important to remember that carbon dioxide concentrations reach toxic levels in work areas during application. Applicators and other workers must wear respiratory protection (a self-contained breathing apparatus) during periods of exposure. Fumigation using atmospheric gases is currently conducted by only a few professional fumigators and by a few large grain companies that maintain equipment at their storage sites. Where available, fumigation with carbon dioxide and/or nitrogen can be cost-competitive and effective.

Once it is aired out, fumigated grain is subject to reinfestation. Surface application of a protectant insecticide should precede or follow fumigation if storage is to continue.

Beneficial Insects

One or more companies are marketing a program that calls for periodic releases of beneficial insects (predators and parasites of pest species) for pest management in stored grains. Although considerable research has been directed at this practice, questions concerning the ability of beneficial releases to lower pest populations to levels required by current grading standards remain unanswered. Published studies conducted in on-farm storages have not achieved adequate levels of control. Farmers and grain handlers who purchase beneficial insects for stored-grain pest management are urged to monitor results very closely.

Where management efforts must be limited to "non-chemical" methods of control, sound cultural practices (sanitation, adequate drying, cleaning, aeration, and annual rotation of the commodity) are extremely important.

SPECIAL CONSIDERATIONS FOR STORED SEEDS

Seed corn in bulk storage (in cribs, bins, granaries, etc.) can be protected from insect damage by using the storage practices and protectant insecticides discussed previously. These practices include proper sanitation, drying, cleaning, and temperature management (aeration) and the use of protectant insecticides such as pirimiphos-methyl (Actellic), malathion, *B.t.*, and pyrethrin plus piperonyl butoxide. Where fumigation of bulk-stored seed corn is necessary, aluminum phosphide

fumigants or carbon dioxide can be used effectively without affecting seed germination. Methyl bromide and chloropicrin reduce or destroy seed germination.

In bagged seed corn (usually not treated with any insecticides) several stored-grain insects may be a problem, but the Indianmeal moth is the most common. Although bulk seed treatments using Actellic or *B.t.* provide residual control of Indianmeal moth larvae, such treatments must be applied before or during bagging. Small quantities of valuable seed can be protected by cool storage or by adding diatomaceous earth to seed packets.

To limit the invasion of untreated, bagged seed corn, warehouses can be fogged periodically during the summer using pyrethrins plus piperonyl butoxide. Using proper warehouse sanitation methods, maintaining cool temperatures, and excluding pests (by using screens, tight-fitting doors and windows, caulking, etc.) also are important. Bagged seed can be effectively fumigated using aluminum phosphide fumigants. Hiring a professional fumigator is advised.

REFERENCES

Stored Grain Insects. 57 pp. USDA Agricultural Handbook No. 500. Available for \$4.50 from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

Fact Sheets available from Agricultural Entomology, University of Illinois, 172 Natural Resources Building, 607 East Peabody Drive, Champaign, IL 61820.

NHE 62 — *Angoumois Grain Moth*

NHE 63 — *Indianmeal Moth*

NHE 64 — *Granary and Rice Weevil*

NHE 65 — *Grain and Flour Beetles*

Picture Sheet X798.01, *Stored Grain Insects and Molds*. Available for purchase from Vocational Agriculture Services, University of Illinois, 1401 South Maryland Drive, Urbana, IL 61801.

Pesticide Applicator Training Packet — Grain Facility Pest Control. Available for \$6.00 from the Office of Agricultural Entomology, University of Illinois, 172 Natural Resources Building, 607 East Peabody Drive, Champaign, IL 61820.

Illinois Pesticide Applicator Training Manual for Seed Treatment — SP39-1. Available for \$2.00 from the Office of Agricultural Entomology, University of Illinois, 172 Natural Resources Building, 607 East Peabody Drive, Champaign, IL 61820.

For a list of addresses of suppliers of insect traps, other sampling equipment, and insecticide application equipment (for stored grains), write to the Office of Agricultural Entomology, University of Illinois, 172 Natural Resources Building, 607 East Peabody Drive, Champaign, IL 61820.

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